MASTER COPY KEEP THIS COPY FOR REPRODUCTION PURPOSES

AD-A260 431

REPORT DOCUMENTATION PAGE

Form Approved OMB No 0704-0188

2

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
4. TITLE AND SUBTITLE THERMAL DIFFUSIVITY MEASUREMENT of DIAMOND MATERIALS		5. FUNDING NUMBERS DAAL-03-92-G-0246
6. AUTHOR(S) L WEI, P.K.KUO, AND R.L. THOMAS		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) WAYNE STATE UNIVERSITY INSTITUTE for MANUFACTURING RESEARCH 666 W. HANCOCK DETROIT, MICHIGAN 48202		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U. S. Army Research Office P. O. Box 12211 Research Triangle Park, NC 27709-2211		10. SPONSORING/MONITORING AGENCY REPORT NUMBER ARO 28780.5-MS

DTIC ELECTE FEB 18 1993 S C D

11. SUPPLEMENTARY NOTES

The view, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The thermal wave/mairage effect technique is applied to the determination of thermal properties of polycrystalline diamond slabs and singie crystal diamonds of different isotopic compositions. This method is weli-suited for these kind of materials.

93-03166

14. SUBJECT TERMS			15. NUMBER OF PAGES
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL

Thermal Diffusivity Measurement of Diamond Materials

L. Wei, P.K. Kuo, and R.L. Thomas

Department of Physics and Institute for Manufacturing Research,
Wayne State University, Detroit, MI 48202, USA

Abstract. The thermal wave/mirage effect technique is applied to the determination of thermal properties of polycrystalline diamond slabs and single crystal diamonds of different isotopic compositions. This method is well suited for these kinds of materials.

1. Introduction

Diamond as a material has many outstanding physical properties. The rareness of large natural single crystals and the high commercial value has prevented large scale applications of many of diamond's usefulness. The only exception is the use as abrasive material of synthetic diamond powder made by high pressure and high temperature processes with a volume exceeding several hundred tons per year. There are two recent developments that are changing the situation. The first is the rapid progress in the technique of making diamond by low temperature, low pressure processes, as witnessed by the increasing number of scientific conferences and publications dedicated to this topic. These processes promise not only high growth rate and large area production of polycrystalline diamonds, but also an end product which has physical properties approaching those of pure diamond crystals. The second is the recent discovery[1] that isotopically enriched diamond crystals are found to have an extraordinarily high thermal conductivity. Single crystal diamonds with 99.9% C^{12} are found to have a thermal conductivity about 50% higher than the best natural diamond crystals which contains 99.1% C^{12}. Since diamond is already the best thermal conductor at room temperature (five times better than copper, a commonly used heat sink material) this fact has obvious scientific and industrial implications.

In order to help optimize the production process, it is important the thermal properties of diamond material be determined accurately, quickly and preferably non-destructively. The thermal wave/mirage effect method developed by the authors in recent years[2,3] has proved to meet this challenge. We report the results of employing this method to measure the thermal diffusivity of thin slab polycrystalline diamonds at room temperature and single crystal diamonds of various isotopic contents over the temperature range 80-300K.

We also introduce a modified Angstrom's method in which the in-solid mirage effect is used to measure directly the temperature gradient in the interior of a diamond crystal. This method offers better accuracy in low temperature range where the the diffusivity of diamond becomes exceedingly high.

2. The Experimental Methods

The thermal wave/mirage effect method for the measurement of thermal diffusivities of layered materials has been reported in detail.[2,3] Briefly, it uses a modulated laser beam focused on the surface of the sample as an alternating heat source to launch a thermal wave in the solid and the surrounding air. A second laser beam is bounced from the surface to detect the temperature gradient in the heated region. Because this method is non-contact, and it can measure distance and time with great precision, it is very suitable for the determination of thermal diffusivities of thin films or thin slab materials.

For single crystal diamond samples, a thin layer of metal film has to be deposited on the surface to act as heat absorber. The film is necessary for any method which requires optical

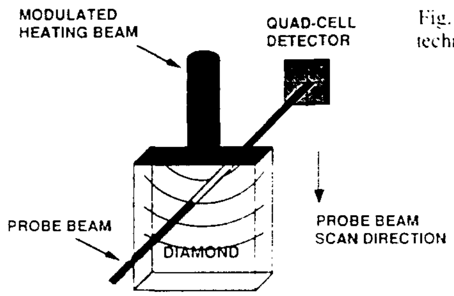

Fig. 1 Schematic diagram of the in-solid-mirage technique in the modified Angstrom method..

heating or infrared detection. At very low temperature, the diffusivity of diamond is expected to rise about three orders of magnitude over its room temperature value. This makes the presence of a metal film not so negligible. For this reason we have resurrected a method used by Angstrom more than a hundred years ago[4]. Angstrom used hot and cold water to launch a thermal wave from one end of a sample and used thermocouples attached to varies locations along the sample to measure the phase and amplitude of the thermal wave as a function of distance of propagation to determine the thermal diffusivity of the sample. In our modified method, the in solid mirage method is used to replace the thermocouples as the temperature probe. The schematic of the experimental arrangement is shown in Fig. 1. The sample is mounted inside a liquid helium dewar with three optical windows. The He-Ne laser for probe beam and the mirage detector are amounted in a single unit called the Monobloc developed by Charbonnier et al[5]. The use of the Monobloc greatly reduces the difficulty of scanning the probe beam relative to the sample and reduces low frequency noises from mechanical vibrations.

3. Results

We have applied our mirage-in-air technique to a variety of polycrystalline diamond slabs produced by a wide varieties of chemical vapor deposition processes. The resulting thermal diffusivities varied widely with process parameters. The internal consistency of this method

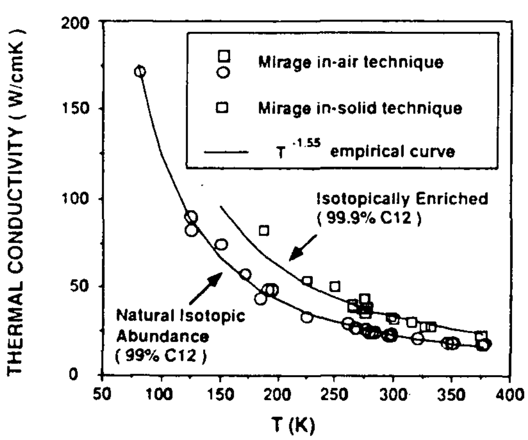

Fig. 2 Results of the mirage in solid and mirage in-air techniques in the measurement of thermalconductivity of single crystal diamonds of different isotopic composition.

has provided manufacturers invaluable information to improve their process control. The comparison with other methods for the determination of thermal properties is currently under way.[6]

We have applied our mirage-in-air technique to single crystal diamonds of different isotopic compositions in the temperature range of 80-300K. The results are summarized in Fig.2.

4. Conclusions

We have demonstrated that the thermal wave/mirage technique is suitable for the determination of thermal properties of diamond materials and it is providing a valuable service to help optimize the production processes.

5. Acknowledgements

This work was partially sponsored by ARO under Contract No. DAAL03-88-K-0089; The General Electric Corporation R&D Center and by the Institute for Manufacturing Research, Wayne State University. We also would like to acknowledge the use of sample supplied by the General Electric Corporation R&D Center and the Double Dee Harris Co.

REFERENCE

1. T.R. Anthony, W.F. Banholzer, J.F. Fleischer, Lanhua Wei, P.K. Kuo, R.L. Thomas, and R.W. Pryor, Phys. Rev. **B42**, 1104 (1990).
2. P.K. Kuo, Lanhua Wei, R.L. Thomas, and R.W. Pryor, Springer Series in Optical Sciences **62**, 124-126, Springer-Verlag, Heidelberg (1990).
3. P.K. Kuo, M.J. Lin, C.B. Reyes, L.D. Favro, R.L. Thomas, D.S. Kim, Shu-yi Zhang, L.J. Inglehart, D. Fournier, A.C. Boccara, and N. Yacoubi, Can. J. Phys., **64**, 1165, (1986); P.K. Kuo, E.D. Sandler, L.D. Favro, and R.L. Thomas, Can. J. Phys., **64**, 1168, (1986).
4. M.A.J. Angstrom, Philo. Mag. **25**, 181, (1863).
5. F. Charbonnier and D. Fournier, Rev. Sci. Instrum. **57**, 6, (1986)
6. G. Lu, and W.T. Swann, First International Conference on the Applications of Diamond Films and Related Materials, August 17-22, 1991, Auburn, Alabama.